The method of wave diagnostics of the oil - and - gas deposit

The given invention refers to the area of the geophysical methods of exploration, in particular, to the seismic survey of the oil-and-gas deposits on the basis of the complex of waves of the different types. The invention is intended for diagnostics of the reservoir and fluid-saturated properties of the rocks, situated in the vicinity of the borehole, and for the reception of the quantitative estimates of the significant oil-field parameters for the identification of the image of the oil-and-gas deposit, and for the subsequent effective baring of the productive layers in the time of exploration and development drilling of the boreholes as well as for the usage of the obtained data for the calculation of oil and gas reserves.

The method is especially effective for diagnostics of the fissured reservoir (limestones, sandstones) because it allows to measure such parameters of the fissured rock as the average length and linear density of fractures, fissured porosity and permeability, fissured residual water saturation and fluid saturation, while the majority of the last cannot be determined with the use of the standard complex of the well logging methods. Besides, the method can be used for the investigation of the lithological and petrophysical parameters of the rocks in situ.

The method of the vibroseism exploration of the oil-and-gas deposits (Ru, Patent № 2045079 GO 1V 1/00, 1995) is known, according to which they generate the seismic oscillations with the frequency of 2 - 20 Hz, register the seismic responses of the earth before and after the excitation of oscillations on three components not less than two geophones simultaneously, and on sharp magnification of the extreme of the received amplitude-frequency characteristics of the seismic response at the frequencies of 2 - 6 Hz make the decision about the presence of the oil-and-gas deposit. The method allows to detect the presence of the oil-and-gas deposit in some cases, though its efficiency is not high as far as the amplitude extreme is the parameter depending on the different factors. In particular, the amplitude values essentially depend on the conditions of the excitation and registration, the absence of data about which can give the false information about the presence of the oil-and-gas deposit.

Therefore, for the identification of installation on such the parameter as the amplitude extreme it is necessary to install the level of amplitude discrimination (or threshold), and for the correct choice of the threshold magnitude the additional information on the statistical properties of useful signal and noise is requiered together with the distribution of probabilities of the amplitudes excess of the useful signal and noise of various levels. The method does not envisage the control over the change of the conditions of the wave generation, and also demands the major expenditures of the time at

the usage of additional devices, as existing vibrators cannot generate the seismic waves in the infrasonic range with the required frequency of the excitations of oscillations.

The method of the investigation of hydrocarbon deposits on the basis of the effects of their nonideal elasticity is known (Rapoport M.B., Ryzhkov V.I. 1992-2000. Scientific Reports at International Geophysical Conferences of SEG, IGRC, EAGE etc). In the above-mentioned method the experimental fact is used, that the hydrocarbon-saturated porous medium has tall absorption properties. It is supposed, that the effects of seismic nonelasticity of the rocks are shown by means of frequency - dependent absorption and dispersion of the phase velocities of the seismic waves, the values of which are calculated according to the data of the surface and borehole seismic survey. On the basis of the method offered by the authors, the investigations of seismic absorbtion according to the surface-seismic survey data (of 2D/3D) were implemented, moreover for the analysis of the absorption parameters the nonstacking seismic data and traceability of the seismic reflections on the temporal cross sections were used. The received values of the absorption parameters are used as the indicators of the hydrocarbon presence in the surface seismic survey. The vertical seismic profiling (VSP) data in the productive boreholes are regarded as parametric at the analysis of seismic nonelasticity and are applied for the separation of the productive thicknesses skipped in the time of well logging, while the downhole observations of VSP, the abnormality absorption parameters and velocity dispersions received by the surface seismic survey, are immediately connected with the oil-and-gas deposits. For the definition of the threshold level, which corresponds to the outline of the deposit, the values of the indicator parameters are calibrated permanently over the results of the tests of the productive boreholes.The usage of the given method allows to define the most perspective in the oil-and-gas-bearing relations of the investigated area, and at the presence of the boreholes also allows to delineate the productive sections.

However, the above-mentioned method uses as calculated of the surface seismic survey data and includes the condition of the mandatory adapting of the investigation results with the well logging data. Because of lapses in the time of parametric measurement and in the presence of only the estimates of effective attenuations of amplitudes the method can give the erroneous prognosis concerning the discovery of layers promising in the oil-and-gas-bearing relation.

Most close according to the technical essence to the declared invention is "The method of the determination of the rheological properties of solid-liquid mediums by means of the multiwave borehole seismic survey" (UA, Patent № 718 C1 G O1 V 1/40, G 01 V 1/00. 15.12.93. Bull. № 2), implementing the principles of borehole seismic survey (prototype). The essence of the invention consists in the following. In the vicinity of the borehole the flat longitudinal wave is formed by

means of the excitation of seismic oscillations by the near-surface sources. By means of the three-component geophones of the displacements (or stresses) the dynamical characteristics of the direct seismic waves in the investigated borehole are recorded, at the same time one of the geophones is oriented along the normal line to the flat wavefront of the longitudinal wave. Then, according to the received kinematic characteristics of the longitudinal and shear (or converted) waves the numeral processing of the dynamical characteristics of the direct longitudinal wave is fulfilled. For this purpose they execute the separation of the monotype temporal signals for the registered downhole components of displacements (or stresses) by pointwise deduction out of the axial component (z - component) the tangential component (x, y - components) of the displacements (or stresses) with the obtaining of the significant parametric estimates of the separate signals in the future.

After that according to the known analytical relationships the kinematic and dynamical parameters are transformed in respect to the bedded values with the further determination of the rheological parameters of the rocks, as well as the absorption parameters of the longitudinal wave for each observation point along the depth of the borehole. The known method of the borehole seismic survey allows over the dynamical characteristics of the direct (downgoing) seismic waves to define the rheological and absorption parameters in porous - fissured layers, which are opened by means of the exploration borehole, and in view of the essential differentiation of the oil-and-gas deposits over rheological properties the reliable information about the physico-mechanical parameters of the rocks in the vicinity of the borehole is received.

However the above-mentioned method ignores the changes of the conditions at the multiple excitation of oscillations by the near-surface sources and the influence of the specified changes on the dynamical parameters of the longitudinal wave. The method also does not envisage the spacial-group processing of the amplitude values of the monotype temporal signals for the receiving of the coefficients of attenuation and energy dispersion of the longitudinal wave. The ultimate aim of the known method does not allow to receive the bedded values of the oil-field parameters for the exact identification of the images of the oil-and-gas deposits.

The kernel of the problem which advantaged the creation of the present invention, consists in the following. The features of the existing technology of the deep borehole drilling with the considerable differentiation of bedded pressures in the rocks along the depth of the borehole is demanded in order the above-mentioned drilling mud heavers will be applied under the specified conditions for the prevention of emergencies, therefore, there is the peening of the part of perspective in the oil-and-gas-bearing relation layers. By the appearance of the drilling mud in last considerable invaded zones qualitative diagnostics of the productive layers by means of the standard methods of well logging becomes ineffective, what in the time of the deposit development

leads to the skip of the average-and low-permeable oil-and-gas-bearing layers and decreases the potential productivity of the boreholes in 1,2 - 1,5 times.

The task, set at making the given invention, is to receive the method of wave diagnostics of the oil-and-gas deposit which by means of the seismic insonification of the vicinity of the borehole will allow over the recording of the displacement vector data in the investigated borehole by means of the three-component seismic profiling to receive the oil-field information on the values of the absorption coefficients, characterizing the type of the fluid saturation; the coefficients of fissuring, granular and fissured permeability, residual water saturation and hydrocarbon saturation of the rocks, including the layers with the considerable invaded zone of the drilling mud.

The existing problem of transition from the observable values of the parameters to their bedded values can be solved by the data special processing, introducing the corrections to the dynamical parameters of the downhole and check data, taking into account the changes of the conditions of the wave excitation and the filtrational effect of the covering thickness of the rocks for each observation point along the depth of the investigated borehole.

The last allows first to calculate the dynamical parameters of the impulse responses of the layers, and then to transform their corresponding petrophysical and oil-field parameters and simultaneously provides the reception of the reliable information about the effective bed thickness and about the location of the gas-oil-water contacts, and also enables to estimate the quality of the cap rocks and to establish the presence of the tectonic dislocations of the investigated borehole of crossing.

The problem is solved in the following way. The method of wave diagnostics of the oil-and-gas deposit which includes the excitation of the seismic waves by the near-surface sources of oscillations, the recording of the displacement vectors for the direct longitudinal and shear waves for each observation point by means of the three-component seismic profiling along the depth of the investigated borehole and the processing of their kinematic and dynamical parameters, characterised that one near-surface source of oscillations executes the excitation in the vicinity of the borehole the longitudinal wave, and their reception is carried out simultaneously in the investigated and check boreholes; after the space orientation of the three-component observation data, the monotype temporal signals for the compression and shear components of the direct longitudinal wave are extracted from the seismic signals which were registered on the axial and tangential components of the displacement vector for the downhole and check devices respectively; further by means of the processing of the kinematic parameters for the direct longitudinal and shear waves the interval values of the elastic moduli (longitudinal and shear) are calculated; after the decoding of the monotype temporal signals the quantitative estimates of

their significant dynamical parameters are made for each component and the observation point according to the downhole and check data, moreover the accuracy of the obtained estimates of the dynamical parameters is monitored by means of the computer modelling of the seismic signals.

Then, carrying out the correction of the corresponding parameter because of the changes of the wave excitation conditions and the filtration of the seismic signals in the covering thickness of the rocks they define the dynamical parameters of the impulse responses, the values of the coefficients of the dynamical viscosity (volumetric and shear) and the absorption (for the compression and shear components) of the layers, when the calibrated values of the absorption coefficients for the compression component are used as the indicators of the hydrocarbon presence and the fluid type in the layers, and also the values of the bedded coefficients of the amplitude attenuation and energy dispersion of the longitudinal wave are calculated; then, using the functional relationships, which are taking into account the thermodynamical conditions of the rock bedding, the obtained petrophysical data are converted into the values of the parameters of the reservoir and fluid-saturated properties of the layers with the aim of the receipt of the necessary totality of the significant oil-field parameters for the identification of the image of the oil-and-gas deposit.

At the same time the depth of the location of the explosive charge (or air gun) for the excitation of oscillations in the near-surface borehole is defined out of the condition of the separation of the direct longitudinal wave from the satellite waves, which are shaped in the time of the reflection from the free surface.

The recording of the displacement vectors for the direct longitudinal (or shear) wave is carried out simultaneously in the investigated and check boreholes, moreover in the investigated borehole - with the help of the three-component multimodular downhole sonde moving along the depth of the borehole, and in the check borehole with the help of the stationary located three-component one-modular sonde. The detailed three-component profiling in the investigated borehole is executed with the step of the discrete observations every 2.5 - 5 m. The check borehole is located on the trajectory of the propagation of the direct longitudinal (or shear) wave and on the line connecting the investigated borehole and the shotpoint at the distance of 20 - 50 m from the last.

Since the seismic waves propagate outside the boundaries of the investigated borehole and insonify the vicinity of the borehole, the reliable diagnostics of such capacitative, filtrational and fluid-saturated properties of the reservoirs in the conditions of their natural bedding is carried out.

Under the given invention all the significant parameters of the reservoir and fluid-saturated properties of the rocks in the radius of 50 - 100 m for the vicinity of the borehole are received, whereas the above-mentioned parameters are not defined with the required completeness by the

standard complex of the well logging methods, which give only the restricted information about the vicinity of the borehole in the radius which is not exceeding 0.5 - 2.5 m.

With the help of the given invention the reliable information about the quantitative parameters of the oil-and-gas-bearing layers can be received, irrespective of the difficulties of the drilling and bedding conditions, the lithological content and the thermodynamical state of the oil-and-gas deposits, that finally reduces the cost price of the drilling expenses and owing to the cutting of the common number of the boreholes maintains the ecological situation in the region of exploration.

For the more complete understanding of the main point of the given invention and its advantages the references to the description are made, which is considered here together with the accompanying figures where the following is represented:

Fig.1 - the seismograms of the direct longitudinal wave for the compression (S) and shear (T) components according to the data of the downhole observation (A) and check observation (B) of 3C VSP for the borehole Lopushna - 13;

Fig.2 - the calculated dynamical parameters of the impulse responses of the rocks: the coefficients of temporal attenuation – of the compression (β_o) and shear (α), the natural frequency (F_o) which are compared to the lithology;

Fig.3 - the calculated rheological parameters of the rocks: the elastic moduli (Lame's constans) - of the compression (λ) and shear (μ); the coefficients of volumetric (λ^*) and shear (η) dynamical viscosity which are compared to the lithology;

Fig.4 - the calculated attenuation and absorption parameters of the rocks (for characteristic frequency $\overline{\omega}=2\pi\cdot 20$Hz): $\alpha'^{,''}(\ln A'^{,''}_0)$ - the effective coefficients of attenuation and $\alpha'^{,''}(\overline{\omega})$ - the coefficients of absorption accordingly for the compression and shear components which are compared to the lithology. The parameter D - a sampling variance;

Fig.5 - the calculated reservoir and fluid-saturated parameters of the rocks: the coefficients of porosity (Φ_g), granular permeability (K_g), residual water saturation ($k'_{r.w.s.}$) and fluid saturation ($k'_{f.s.}$) with the definition of the fluid type, filling the pore space of the reservoir, which are compared to the lithology;

Fig.6 - the calculated reservoir and fluid-saturated parameters of the rocks: the average length of fractures (l), the linear density of fractures ratio ($L_{d.f.}$), the coefficients of fissured permeability (K_f) and fluid saturation ($k''_{f.s.}$) with the definition of the fluid type, filling the fissured space of the reservoir, which are compared to the lithology.

The diagnostics of the dynamical, rheological, absorbing, reservoir and fluid-saturated properties for the rocks in the vicinity of the borehole is based on the combined deformation model of the vertically - inhomogeneous viscoelastic isotropic solid medium for the isothermal case,

proposed by the author [Briginevich V.A. 1991. The combined model of deformation and the conditions of longitudinal wave propagation in a viscoelastic solid. Geophys.Journal. 10(3), 388-405]. According to the combined model at the deforming of vertically - inhomogeneous viscoelastic isotropic solid medium such observationally measured macroscopical parameters as the displacements, stresses, elastic moduli, the coefficients of dynamical viscosity and others directly depend on the microscopical parameters of the real solid medium such as microstructure of the matrix material (grains), the sizes of the micropores, microfissures and their fluid saturation, moreover their activity is shown through the total response of the last to the enclosed exterior action in the shape of average the statistical values of the porosity, fissuring, permeability, water and fluid saturations.

The combined deformation model of the vertically-inhomogeneous viscoelastic solid medium is determined by the equations, which for the rectangular coordinate system x,y,z characterize the following stressed and deformed state: $\sigma_z > \sigma_x = \sigma_y$; $\sigma_{xz} = \sigma_{xy} = \sigma_{zx} = 0$; $\varepsilon_z \neq 0$; $\varepsilon_x = \varepsilon_y = 0$, where $\sigma_{x,y,z}$ - normal stresses; σ_{xz}, σ_{xy}, σ_{zx} - tangential stresses; $\varepsilon_{x,y,z}$ - linear deformations, which arise in the solid medium during the propagation of flat longitudinal wave, moreover the equations are represented for the components of the stress vector in the operator form:

$$\sigma_z = \left[\left(\lambda + \lambda^* \frac{\partial}{\partial t}\right) + 2\mu \frac{\partial}{\partial t} \Big/ \left(\frac{\mu}{\eta} + \frac{\partial}{\partial t}\right)\right]\varepsilon_z , \qquad (1) \qquad \sigma_{x,y} = \left(\lambda + \lambda^* \frac{\partial}{\partial t}\right)\varepsilon_z , \qquad (2)$$

where $\lambda = \lambda(z)$, $\mu = \mu(z)$ - the compression and shear moduli (Lame's coefficients); $\lambda^* = \lambda^*(z)$, $\eta = \eta(z)$ - the coefficients of the volumetric and shear dynamical viscosity, respectively. According to the form of the equations of the state (1,2), which satisfy the movement equation: $\frac{\partial \sigma_i}{\partial x_i} = \rho \frac{\partial^2 U_i}{\partial t^2}$, where $\rho = \rho(z)$ - the density; i = (x,y,z) we receive the homogeneous wave equations for the components of displacements of the flat longitudinal wave propagating in the direction of the axis oz:

$$\left\{\beta \frac{\partial}{\partial t}\left(\frac{\partial^2}{\partial t^2} + 2\alpha \frac{\partial}{\partial t}\right) \Big/ \left[\frac{\partial^2}{\partial t^2} + (2\alpha + \beta)\frac{\partial}{\partial t} + \omega_0^2\right]\right\} U_z = V_p^2 \left[\frac{\partial^2}{\partial z^2} + \frac{\partial \ln(\lambda + 2\mu)}{\partial z} \cdot \frac{\partial}{\partial z}\right] \cdot U_z , \qquad (3)$$

$$\left[\rho \frac{\partial^2}{\partial t^2} + \lambda^* \frac{\partial^3}{\partial z^2 \cdot \partial t} + \lambda \frac{\partial^2}{\partial z^2}\right] \cdot U_{x,y} = 0 , \qquad (4)$$

where $U_{x,y,z} = U_{x,y,z}(z,t)$ - the components of the displacement vector for rectangular axes x,y,z; $V_p = V_p(z) = [(\lambda+2\mu)/\rho]^{1/2}$ - the local velocity of the longitudinal wave; $\omega_0 = (\lambda\mu/\lambda^*\eta)^{\frac{1}{2}}$ - the angular frequency of natural oscillations; $\alpha = \mu / 2\eta$ - the shear coefficient of attenuation; $\beta = (\lambda + 2\mu)/\lambda^*$ - the volumetric coefficient of attenuation.

Within the the correct statement of the nonstacionary mixed problem on radiation in case of the inhomogeneous initial and homogeneous boundary conditions of the impedance type which are executed on the flat wavefront of the direct longitudinal wave, when $t > 0$, $z > 0$, the solution of the equations (3,4) or the impulse responses of the deformation for the above - mentioned medium, using the method of Fourier, have been received for the component of displacements in the shape:

$$\begin{cases} U_z(z,t) = \dfrac{A_0}{(\lambda+2\mu)^{1/2}}\left[\dfrac{1}{\beta_0}\cdot e^{-\beta_0 t} - B_0 e^{-\alpha t}\sin(\omega t+\varphi_0)\right]\cdot\exp(i\bar{k}z), & (5)\\ U_{x,y}(z,t) = -A_0\cdot B_0 e^{-\alpha t}\cdot\sin(\omega t+\varphi_0)\cdot\exp(-\bar{k}_\lambda z), & (6)\end{cases}$$

where A_0 = const; $\omega = (\omega_0^2 - \alpha^2)^{\frac{1}{2}}$ - the angular frequency of attenuaton oscillations; $\beta_0 = \omega_0^2/\beta$ - the coefficient of volumetric attenuation; $B_0 = (\alpha^2+\omega^2)^{\frac{1}{2}}/\alpha\omega$ - amplitudes; $\varphi_0 = arctg(\omega/\alpha)$ - the initial phase; $\bar{k} = \bar{k}(z) = \int\limits_0^z \left[k_p^2 - (\lambda+2\mu)^{-1/2}\cdot\dfrac{d^2}{dz^2}(\lambda+2\mu)^{\frac{1}{2}}\right]^{1/2} dz$; $k_p = k_p(z) = \omega_0/V_p$ - the local wavenumber; $\bar{k}_\lambda = \int\limits_0^z k_\lambda dz$; $k_\lambda = k_\lambda(z) = \omega_0/V_\lambda$ - the coefficient of absorption; $V_\lambda = V_\lambda(z) = (\lambda/\rho)^{\frac{1}{2}}$; i - the imaginary unit.

The above-mentioned solution of a direct problem allows to predict the superposition of two monotype temporal signals in the direction of the propagation of the direct flat longitudinal wave for each point of the vertically-inhomogeneous viscoelastic solid medium. The presence of the dual impulse response during the longitudinal wave propagation is defined by the conditions of the stress-deformed state of the liquid-porous (for compression component) and fracture-brittle (for shear component) elements of the dynamically deformable solid medium.

Therefore, the monotype temporal signals which are excited in the continuous solid medium by the flat longitudinal wave, will consist of two the damped processes differing by the polarities, amplitudes, temporal coefficients of attenuation, instantaneous frequencies and initial phases, and only one of these processes can be clearly observed on the shear components of the displacement vector. Really, from the experimental data of the polarization method of VSP is known, that the direct longitudinal wave propagating in the stratified solid medium is polarized linearly for the first and is nonlinearly for the subsequent phases of the seismic impulses (Galperin E.I. 1984. Polarization method of seismic prospecting. D. Reidel Publications Co).

It is provided that on the flat wavefront of the longitudinal wave propagating in the direction of the axis oz, the following boundary coditions of the stationary type for the component $U_z(z,t)$ are carried out: $\left(\dfrac{d^2}{dz^2} + \dfrac{d\ln(\lambda+2\mu)}{dz}\dfrac{d}{dz} + k_p^2\right)U_z(z)\Big|_{z\le 0} = 0$, the equation (3) is converted to the form:

$$\left[\beta\frac{\partial}{\partial t}-V_p^2\left(\frac{\partial^2}{\partial z^2}+\frac{\partial\ln(\lambda+2\mu)}{\partial z}\frac{\partial}{\partial z}\right)\right]\left[\frac{\partial^2}{\partial t^2}+2\alpha\frac{\partial}{\partial t}-V_p^2\left(\frac{\partial^2}{\partial z^2}+\frac{\partial\ln(\lambda+2\mu)}{\partial z}\frac{\partial}{\partial z}\right)\right]\cdot U_z(z,t)=0.$$

From this equation according to Bodgia theorem we received:

$$\left[\beta\frac{\partial}{\partial t}-V_p^2\left(\frac{\partial^2}{\partial z^2}+\frac{\partial\ln(\lambda+2\mu)}{\partial z}\frac{\partial}{\partial z}\right)\right]U_z'(z,t)=0\ (7);\ \left[\frac{\partial^2}{\partial t^2}+2\alpha\frac{\partial}{\partial t}-V_p^2\left(\frac{\partial^2}{\partial z^2}+\frac{\partial\ln(\lambda+2\mu)}{\partial z}\frac{\partial}{\partial z}\right)\right]U_z''(z,t)=0\ (8),$$

where $U_z(z,t)=U_z'(z,t)+U_z''(z,t)$. If the boundary conditions are executed, each of the equations (7), (8) will fulfil to the sample solutions for the harmonic components: $U_z{}^{','}(z,t)=e^{-i\bar{\omega}t}\exp[i\bar{k}(\bar{\omega})z]$(9), where the characteristic angular frequency $\bar{\omega}$ will be the independent variable; $\bar{k}(\bar{\omega})$ - the complex wavenumber; $k(\bar{\omega})=\bar{\omega}/V(\bar{\omega})$ - the real wavenumber; $\tilde{\alpha}(\bar{\omega})$ - the coefficient of attenuation; V($\bar{\omega}$) - the propagation velocities of the harmonic components. Taking into account the second approximation of the VKBD method ($k(\bar{\omega})=k_p$), the solutions (9) will be true if: $V(\bar{\omega})=V_p\bar{\omega}/\omega_0$, $\tilde{\alpha}^{','}(\bar{\omega})=\alpha^{','}(\bar{\omega})$ + $\bar{\alpha}^{','}$, where $V(\bar{\omega})$, $\tilde{\alpha}^{','}(\bar{\omega})$ - the propagation velocity and the coefficients of attenuation; $\alpha'(\bar{\omega})=\beta\bar{\omega}/2V_p\omega_0$ and $\alpha''(\bar{\omega})=\alpha\bar{\omega}/V_p\omega_0$ - the absorption coefficients, characterizing the rheological (viscoelastic) properties of the solid medium; $\bar{\alpha}^{','}=\dfrac{d\ln(\lambda+2\mu)}{dz}$ - the coefficient of attenuation, characterizing gradient properties of the elastic parameters in the solid medium for $U_z'(z,t)$ and $U''_z(z,t)$, respectively.

The description of the propagation of the direct flat longitudinal wave in each point of the stratified vertically-inhomogeneous viscoelastic solid medium is possible while using the convolutional model and approximations of the wavelets by means of the analytical function Berlage representing the description of the wide class of the monotype temporal signals.

Hence the impulse responses of the above-mentioned deformation medium for the components of the displacement vector may be offered in the form:

$$\begin{cases}\bar{u}_{x,y}(z,t)=-A_1''t^{\bar{p}''}\exp(-\bar{\alpha}t)\sin(\bar{\omega}''t-\bar{\varphi}_0'')\exp(-\bar{k}_\lambda z)\\ \bar{u}_z(z,t)=\left[A_1't^{\bar{p}'}\exp(-\bar{\beta}_0 t)\sin(\bar{\omega}'t-\bar{\varphi}_0')-A_1''t^{\bar{p}''}\exp(-\bar{\alpha}t)\sin(\bar{\omega}''t-\bar{\varphi}_0'')\right]\exp(i\bar{k}z)\end{cases}$$

where $\bar{u}_{x,y,z}(z,t)$ - the displacements for the x,y,z - components; A_1', A_1'' - the amplitudes dependent on the coefficients of the wave transmission in the layers; $\bar{p}^{','}$ - the exponents of steepness; $\bar{\beta}_0, \bar{\alpha}$ - the temporal coefficients of attenuation; $\bar{\omega}^{','}$ - the angular frequencies; $\bar{\varphi}_0^{','}$ - the initial phases for the compression (′) and shear (″) components, respectively.

The physical observations of the three-component VSP data for the recording of the displacement vector are realized in the vertical cylindrical boreholes which are located in the stratified vertically-inhomogeneous viscoelastic solid medium. According to the classical

mechanics of the continuous medium the borehole is the concentrator of stresses and deformations in the above-mentioned medium. It is known, that in the presence of orthogonality of the axis oz the boreholes concerning the wavefront of the flat longitudinal wave, the wavelength considerably exceeds the diameter of the borehole 2a, where a - the radius of the borehole. Therefore, for the wavefield components and observations on the wall of the cylindrical borehole the author has received the special solution of the problem, where in the calculation is based on the following.

If the vicinity of the borehole is considered in the cylindrical coordinate system with the ordinate oz, directional along an axis of the borehole, then the boundary conditions on the borehole wall for the stresses are usually set in the form: $\sigma_r\big|_{r=a}=0;\sigma_\theta\big|_{r=a}=2\sigma_\theta;\sigma_z\big|_{r=a}=\sigma_z$, where $\sigma_r,\sigma_\theta,\sigma_z$ - the normal stresses for the radial, tangential and axial components. According to the received solution the components of the displacement vector which are formed by the direct flat longitudinal wave on the borehole wall, propagating in the vicinity of the borehole in the direction of the axis oz, are:

$$\begin{cases} u_r(z,t)=0; \quad u_\theta(z,t)=-\sqrt{2}\widetilde{A}_1''t^{\widetilde{p}''}\exp(-\widetilde{\alpha}t)\sin(\widetilde{\omega}''t-\widetilde{\varphi}_0'')\exp(-\bar{k}_\lambda z), \\ u_z(z,t)=\left[\widetilde{A}_1't^{\widetilde{p}'}\exp(-\widetilde{\beta}_0 t)\sin(\widetilde{\omega}'t-\widetilde{\varphi}_0')-\widetilde{A}_1''t^{\widetilde{p}''}\exp(-\widetilde{\alpha}t)\sin(\widetilde{\omega}''t-\widetilde{\varphi}_0'')\right]\exp(i\bar{k}z), \end{cases}$$

where the index (~) designates the estimated parameters.

Then at excitation of the direct longitudinal wave in the vicinity of the borehole and during the observations of displacements on the borehole wall the superposition of the monotype temporal signals on the axial (or longitudinal) component is defined: $u_z(z,t)\big|_{z=H}=u_z(t)=u_z'(t)+u_z''(t)$, whereas on the tangential (or transverse) component: $u_\theta(z,t)\big|_{z=H}=u_T(t)$ only one monotype temporal signal is observed: $u_T(t)=u_z'(t)$. Hence, it follows: $u_z'(t)=u_z(t)-u_\theta(t)/\sqrt{2}=u_S(t)$, where $u_S(t),u_T(t)$ - the displacements characterizing the monotype temporal signals for the compression (S) and shear (T) components, accordingly.

The process of the utilization of the invention includes: the observations of the wavefield in the investigated and check boreholes with the necessary fullness (registration of the displacement vectors by means of 3C VSP) and necessary detail (the compact step for the observation points at the profiling of the investigated borehole); the digital recording of the seismic waves in the wide-band dynamical and frequency ranges; the data processing of 3C VSP with the purpose of their transformation from the observation point of view to the data caused by the observation system (the near-surface source of the wave excitation while the geophones are in the borehole) to the aspect of the data which represent the values of the dynamical parameters of the impulse responses of the

rocks, and then will be carried out by the geological interpretation by means of the petrophysical data converting to the values of the petroleum-field parameters for the layers of the rocks.

The procedures of the downhole observations envisage the recording of the three-component data in two boreholes simultaneously, moreover one of them - the investigated borehole where measurements are realized by means of profiling of the lengthways depth of the borehole with the three-component multimodular downhole sonde, and another - the check borehole in which the three-component one-modular sonde is located stationary.

For the oscillation excitation one near-surface source (the shotpoint) is used, moreover the distance of the last from the investigated borehole does not exceed 50-100 m. The oscillation excitation is realized by the known method, for example, by means of the location in the near-surface borehole of the explosive charge (or the air gun) at the optimum depth which guarantees the receiption of the maximal energy and the simple shape of the seismic wavelets of the direct longitudinal wave.

The optimum depth of the location of the explosive charge (or the air gun) is determined by means of the execution of the obligatory condition of the separation of the direct longitudinal wave from the satellite waves, which are shaped in the time of reflection from the free surface. Simultaneously the force of the impulsive action at the excitation of oscillations, determined by the weight of the charge (or the air gun power) and the seismogeological conditions of its location, should guarantee the reception of such energy of the direct longitudinal wave in the investigated borehole in order to enable the seismogram of the tangential component for the downhole three-component sonde to distinguish the useful signal in the background of the noise (the signal-to-noise ratio must exceed 1).

For the registration of the conditions change of the nonsingle excitation of oscillations during the production of works on the investigated borehole the check borehole is used, located close to the area of the excitation and on the trajectory of the direct waves between the investigated borehole and the shotpoint at the distance of 20-50 m from the latter. The three-component one-modular sonde is dipped in the check borehole to the depth below the depths of the location of the explosive charge (or the air gun).

The borehole investigations are conducted by means of the standard equipment with the digital recording of the seismic signals, which implements on the open channel with the sampling interval of 0.5 ms and in the time of absence of the amplitude adjustments. The investigations are conducted in the borehole at the perspective in the oil-and-gas-bearing relation interval of depths (length 300 - 500 m) by means of the detailed three-component profiling the latter with the step of the discretic observations every 2.5 - 5 m.

The method of the data processing of the downhole observations is based on the solution of the inverse problem for the case of normal plane waves incidence. The method envisages the data processing of the three-component observations which preliminarily are oriented in the space, and the extraction of the monotype temporal signals for the compression and shear components from the seismic impulses which are observed experimentally on the axial and tangential components of the displacement vector of the direct longitudinal wave for the downhole and check devices. The procedures of the digital extraction of the components and respective monotype temporal signals were considered earlier.

On the first stage of processing by means of the parametric analysis of the seismic traces the monotype temporal signals are decoded according to the compression and shear components of the longitudinal wave with the further receiving of the quantitative estimates of their significant dynamical parameters such as the initial amplitude, the exponent of steepness, the temporal coefficients of attenuation, the instantaneous frequency and the initial phase.

The parametric analysis of the monotype temporal signals together with the procedure of the determination of the numerical estimates of their dynamical parameters is performed with the use of the approximation of the seismic wavelets by the analytic Berlage function which allows to represent adequately the typical monotype temporal signals by means of totality of only five significant dynamical parameters:

$$U_{S,T}(z,t) = \tilde{A}_0{}^{','''} t^{\tilde{p}^{','''}} \exp\left[-(\tilde{\beta}_0, \tilde{\alpha})t\right] \sin(2\pi\tilde{F}^{','''} t + \tilde{\varphi}_0{}^{','''}),$$

where the estimated parameters: $\tilde{A}_0{}^{','''}$ - the initial amplitudes; $\tilde{p}^{','''}$ - the exponent of steepness; $\tilde{\beta}_0, \tilde{\alpha}$ - the temporal coefficients of attenuation; $\tilde{F}^{','''}$ - the instantaneous frequencies and $\tilde{\varphi}_0{}^{','''}$ - the initial phases of the monotype temporal signals.

In the invention the opportunity of receiving of the most precise values of the parameter is taken into account, since each of the dynamical parameters at measuring its value will have biased estimates. The latter is achieved by means of the computer modelling of the monotype temporal signals, according to which the received quantitative estimated parameters by means of the model of the synthetic signal are compared visually to the observed monotype temporal signal and the next are the corrected with the application of the optimal deciding rules.

It is important, that the prognosis of the shape of the monotype temporal signals ensures the receiving of the estimates of their dynamical parameters for each observation point of the lengthways depth of the borehole. The estimated parameters can be numerically corrected for converting them from the observable values into the type of bedded values. For this purpose, using the observation downhole and check data for the respective component of the direct longitudinal

the observation downhole and check data for the respective component of the direct longitudinal wave, they separately calculate the estimated dynamical parameters of the monotype temporal signals, and after the improvement of the received values of the estimates by means of the computer modelling execute the correction of their values according to the algorithms, offered by the author, by the recalculation of the parameters, characterizing the impulse responses of the rock layers.

Gaining the dynamical parameters of the monotype temporal signals according to the postulate of the linearity for displacements, properties of reciving and the recording devices the problem of the linear filtration can be considered, moreover the seismic channel has the impulse and frequency characterizations. For exception of the distorting effect owing to the activity of the recording channel and for the exception of the conditions change of the wave excitation at the beginning the numerical correction of the estimated dynamical parameters ($\tilde{\beta}_0, \tilde{\alpha}; \tilde{\omega}''$) for the monotype temporal signals of the downhole observations is implemented by means of the use of the analogical parameters out of the check observation data according to the dependencies: $(\beta_o,\alpha)_{bor.} = 2(\tilde{\beta}_0, \tilde{\alpha})_{bor.}$ - $(\tilde{\beta}_0, \tilde{\alpha})_{check}$; $\omega''_{bor.} = 2\ \tilde{\omega}''_{bor.} - \tilde{\omega}''_{check}$, where $(\tilde{\beta}_0, \tilde{\alpha}; \tilde{\omega}'')_{bor.}$ and $(\tilde{\beta}_0, \tilde{\alpha}; \tilde{\omega}'')_{check}$ – the estimated values of the dynamical parameters for the downhole and check data and the respective observation point. Then the correction of the revised estimates of the dynamical parameters is implemented by means of the layer-stripping method $(\beta_o,\alpha;\omega'')_{bor.}$, that allows to delete the distortions of the parameters for the downhole observations, caused by the filtrational effect of the covering thickness of the rocks, and also to convert the latter parameters into the respective parameters of the impulse responses of layers.

The recalculation of the revised estimates in the interval values of the dynamical parameters of the impulse response for the separate layer is carried out according to the following formulas: $(\beta_o,\alpha)_{layer} = 2\ p'^{''}_j\ (\beta_o,\alpha)_j - (\beta_o,\alpha)_{j-1}$; $\omega''_{layer} = 2\ p'^{''}_j \omega''_j - \omega''_{j-1}$, where $(\beta_o,\alpha;\ p'^{''},\omega'')_j$ - the values of the revised estimates of the dynamical parameters for the j-observation point; $(\beta_o,\alpha;\omega'')_{j-1}$ - the values of the revised estimates of the dynamical parameters for the (j-1) observation point lengthways depth of the borehole; $(\beta_o,\alpha,\omega'')_{layer}$ - the interval values of the dynamical parameters of the impulse response of the layer.

On the second stage of the processing the interval values of the elastic moduli are defined which are calculated by means of the use of the kinematic parameters of the longitudinal and shear (or converted) waves. The joint use of the kinematic parameters and the density log data allows to define the numerical values of such elastic moduli as longitudinal - $\lambda+2\mu = \rho V_p^2$ and shear - $\mu = \rho V_s^2$, where λ, μ - Lame's coefficients; $V_{p,s}$ - the velocities of longitudinal and shear waves and

ρ - the density. Using the values of the dynamical parameters of the impulse responses and the elastic moduli for the rock layers, the values of such rheological parameters as the coefficients of the dynamical viscosity: $\lambda^* = (\lambda + 2\mu) / \beta$ (for the volumetric viscosity) and $\eta = \mu / 2\alpha$ (for the shear viscosity) are calculated.

On the third stage for the previously separated layers (according to the lithologic data) the special-group processing of the estimated values of initial amplitudes ($\widetilde{A}_0{}'{}''$) and the longitudinal elastic modulus ($\lambda+2\mu$) are implemented. The given invention envisages the possibilities for increasing the accuracy of the obtaining of the amplitude estimates of the seismic impulses of the direct longitudinal wave: by means of the use of the monotype temporal signals; obtaining their estimates of the initial amplitudes ($\widetilde{A}_0{}'{}''$); the corrections of estimated values of the above-mentioned amplitudes for the decrease of their straggling owing to the change of the conditions in the time of the multiple wave excitation and their subsequent normalization for the compensation of the geometrical divergence of the wavefront (owing to the difference of the latter from ideally flat) for the compression and shear components of the direct longitudinal wave, accordingly.

After the calculation of the calibration coefficients out of the check observation data and the correction of the estimated values of the initial amplitudes for the downhole observation data the normalization of the above-mentioned amplitudes is performed with the aim of the compensation of the geometrical divergence of the wavefront of the direct longitudinal wave. Further, according to the revised and normalized values of the initial amplitudes for the each observation point lengthways depth of the borehole and for the longitudinal wave the respective component the coefficient of the effective attenuations for the j-layer is calculated: $\widetilde{\alpha}'{}''_{\text{eff.att.}} = (\ln A_{0j2}{}'{}'' - \ln A_{0j1}{}'{}'') / \Delta H_j$, where $A_{0j1}{}'{}''$, $A_{0j2}{}'{}''$ - the values of amplitudes on the upper (j_1) and lower (j_2) boundaries of the j-layer with the thickness ΔH_j, which are defined statistically by means of the least squares method using the declination of the profile of the change of the natural logarithm of amplitudes ($\ln A_{0j}{}'{}''$) for the estimated interval of depths.

The coefficients of attenuation for the direct longitudinal wave according to the combined deformation model of the vertically-inhomogeneous viscoelastic solid medium are as follows: $\widetilde{\alpha}'{}''(\overline{\omega}) = \overline{\alpha}'{}'' + \alpha'{}''(\overline{\omega})$, where $\overline{\alpha}'{}''$ - the attenuation coefficients characterizing the gradient properties of the elastic parameters; $\alpha'{}''(\overline{\omega})$ - the absorption coefficients characterizing the rheological properties of the layers of the rocks for the compression and shear components, respectively.

The real solid medium usually is thin-layering which at the definite assumption for the separate thick layer can be regarded as the gradient (or vertically - inhomogeneous) medium. Then the

coefficient of attenuation $\alpha'{}^{,\prime\prime}(\bar{\omega})$, characterizing the effects of energy dispersion in thin-layering beds, can be calculated by means of the least squares method according to: $\bar{\alpha}'{}^{,\prime\prime} = \ln(\lambda+2\mu)_{j2} - \ln(\lambda+2\mu)_{j1}] / \Delta H_j$, where $(\lambda+2\mu)_j$ - the values of the longitudinal elastic modulus on the upper (j_1) and lower (j_2) boundaries of the j-layer with the thickness ΔH_j. The distinctive feature of the method for the calculation of the absorption coefficients $\alpha'{}^{,\prime\prime}(\bar{\omega})$ in the given invention there is the opportunity of the use of only values of the temporal dynamical parameters (β, α, ω_o) and the velocities of the longitudinal wave V_p in the layer to the obtaining of the above-mentioned absorption coefficients.

The absorption coefficients, linearly-dependent from the characteristic angular frequency $\bar{\omega}$, are calculated for each observation point lengthways depth of the borehole according to formulas: $\alpha'(\bar{\omega}) = \beta\bar{\omega}/2V_p\omega_o$; $\alpha''(\bar{\omega}) = \alpha\bar{\omega}/V_p\omega_o$, and the quality factors (Q-factors) are calculated according to: $Q'(\bar{\omega}) = \omega_o^2/\beta\bar{\omega}$; $Q''(\bar{\omega}) = \omega_o^2/2\alpha\bar{\omega}$ for the compression and shear components, accordingly, where $\omega_o = 2\pi F_o$ - the angular frequency of natural oscillations; $\beta = \omega_o^2/\beta_o$ - the temporal coefficient of volumetric attenuation. The received interval values of the absorption coefficients $\alpha'{}^{,\prime\prime}(\bar{\omega})$ later are averaged statistically by means of the least squares method on the interval of the depths of the layers.

The author has established experimentally that the calibrated values of the absorption coefficient $\alpha'(\bar{\omega})$ for the compression component of the longitudinal wave can serve as the indicator of the hydrocarbon presence in the reservoir, since the seismic nonelasticity of the last is conditioned by such its properties as the porosity, fracturing, permeability and fluid saturation (Brygynevych V. A. 1997. REOKONA seismic technology studies reservoir and fluid - saturated properties of the rocks in the vicinity of borehole. 59th EAGE Conference, Geneva, Switzerland, Extended Abstracts, P075). Therefore, the calibrated values of the absorption coefficient $\alpha'(\bar{\omega})$ for the compression component of the longitudinal wave are used to receive the quality estimates of the fluid type, filling the pore and fissured space in the rocks. In this connection the calibration conditions are offered: $\alpha'_w(\bar{\omega})<\alpha'_o(\bar{\omega})<\alpha'_g(\bar{\omega})$, where the quantitative values of the absorption coefficient are compared: for water - $\alpha'_w(\bar{\omega})$, oils - $\alpha'_o(\bar{\omega})$ and gas - $\alpha'_g(\bar{\omega})$, respectively. The calibrated values of the absorption coefficient for the compression component depends on the characteristic frequency $\bar{\omega}$. Thus, for the frequency $\bar{\omega} = 2\pi\cdot 20$ Hz the numerical values of the absorption coefficient changes within the limits: for water - $\alpha'_w(\bar{\omega}) = (1\text{-}4)10^{-3}\ m^{-1}$, for oil - $\alpha'_o(\bar{\omega}) = (5\text{-}7)10^{-3}\ m^{-1}$ and for gas- $\alpha'_g(\bar{\omega}) = (8\text{-}10)10^{-3}\ m^{-1}$.

In their turn, the calibrated values of the absorption coefficient $\alpha''(\bar{\omega})$ for the shear component of the longitudinal wave changes in the reverse order: $\alpha''_w(\bar{\omega})>\alpha''_o(\bar{\omega})>\alpha''_g(\bar{\omega})$,, where the

absorption coefficients are: for water - $\alpha''_w(\overline{\omega})$, oils - $\alpha''_o(\overline{\omega})$ and gas - $\alpha''_g(\overline{\omega})$, respectively. It has been determined that during the change of the fluid type, filling the pores and fractures in the rocks, the absorption coefficients $\alpha'{,}''(\overline{\omega})$ for the compression and shear components change in the opposite directions.

As the calculation of the estimates of attenuation $\overline{\alpha}'{,}''$ and absorption $\alpha'{,}''(\overline{\omega})$ is performed, using the independent data, that becomes possible owing to the numeral definition of the coefficient characterizing scattering of the longitudinal wave on the local intrastratal inhomogeneities according to the expression: $\tilde{\alpha}'{,}''_{disp.} = \tilde{\alpha}'{,}''_{eff.att.} - [\overline{\alpha}'{,}'' + \alpha'{,}''(\overline{\omega})]$, where $\tilde{\alpha}'{,}''_{disp.}$- the coefficient of dispersion on the local inhomogeneities of the j-layer with the thickness ΔH_j. The estimated coefficient of dispersion $\tilde{\alpha}'{,}''_{disp.}$ are indicators of the stressed state of the separated layers and allow to obtain the additional information, for example, about the zones with the anomalous high bedded pressures.

The interpretating stage envisages the choice of the necessary totality of the measured oil-field parameters which with the sufficient completeness characterizes the reservoir and fluid-saturated properties of the deposit, moreover their information density guarantee the exact identification of the images of the oil-and-gas deposits.

The totality of the significant oil-field parameters, including the coefficients of porosity (Φ), the linear density of fractures ($L_{d.f.}$), granular (K_g) and fissured ($K_{f.}$) permeabilities, residual water saturation ($k'{,}''_{r.w.}$) and fluid saturation ($k'{,}''_{f.s.}$), quite unequivocally characterizes the capacitative, filtrational and fluid-saturated properties of the oil-and-gas-bearing layers formative the oil-and-gas deposit, moreover the above-mentioned parameters can be used as the indicators for the identification of the image of the oil-and-gas deposit. For the transformation of the petrophysical parameters to the form of the oil-field geology data - attributes of recognizable object the author offers the functional relationship which are taking into account the termodynamical conditions of the layers of the rocks.

For the model of the pore-containing rock (or liquid-porous element of the deformable solid medium) granular permeability of the rock depends on the values of the average radius of the pore capillaries R_o, which can be calculated, as follows: $R_o = 2\Omega D_o \lambda^*/kT$, where Ω - the atomic volume; D_o - the diffusion constant of atoms; k - Boltzmann's constant; T - Kelvin's temperature (°K). According to Pauzel's and Darsy's laws the granular permeability is defined following the formula: $K_g = \Phi_g R_o^2/8P^2$, where P - the meanderingness of the pore channels coefficient and Φ_g - the coefficient of granular porosity.

The coefficient of granular porosity for the rock can be calculated as: $\Phi_g = (\rho_s - \rho)/(\rho_s - \rho_l)$, where ρ, ρ_s, ρ_l are the common, solid and liquid phases of density, moreover the parameters ρ, ρ_s, ρ_l are defined, using the density log data, the lithological data and calibrated values of the absorption coefficients for the compression component of the longitudinal wave. Hence, coefficient of the granular permeability, taking into account the previous formula, is as follows: $K_g = (\Phi_g \Omega D_o \lambda^*)/kTP^2$, where the parameter P is calculated by means of the formula: $P = \Phi_g^{-m}$, moreover m = 1.82 (for the terrigenous rocks) and m = 2.03 (for the carbonate rocks). Then the coefficient of residual water saturation for the porous medium can be defined according to: $k'_{r.w.} = (\Phi_g^{1/2}\tau') / [(2K_g)^{1/2}(1-\Phi_g)P$, where τ' - the average thickness of the lamina of the fixed water.

For the model of the fracture-containing rock (or the fracture-brittle element of the deformable solid medium) the subhorizontal fissuring caused by the microfissures of the limited length, is characterized by means of such parameter as the linear density of fractures ratio, which is calculated here according to: $L_{d.f.} = (1.25\ kTl)/\Omega D\eta$, where l - the average length of microfissures; D - the diffusion constant of vacancies. Then the coefficient of fissured porosity is calculated, using the formula: $\Phi_f = L_{d.f.}b_{f.}$, where $b_{f.}$ - the average width (or opening) of microfissures. The opening of the fractures is calculated according to: $b_{f.} = b_0\exp[\beta_{f.}\ (p_{res.} - p_{sd.})]$, where b_0 - the initial width of microfractures; $\beta_{f.}$ - the coefficient of fissured compressibility; $p_{res.}$, $p_{sd.}$ - the bedded and lateral mining pressures, accordingly. At the same time the coefficient of fissured permeability can be represented as follows: $K_f = (L_{d.f.}b_{f.}^3 10^{-6})/12$. Hence, the coefficient of the residual water saturation is defined according to: $k''_{r.w.} = (\Phi_f^{1/2}\ \tau'')/ [3K_f)^{1/2}(1-\Phi_f)$, where τ'' - the average thickness of the lamina of the fixed water.

Finally, the coefficients of fluid saturation of the rock are calculated according to the formula: $k'{,}''_{f.s.} = (1 - k'{,}''_{r.w.})$. If for the obtaining of the parametrical estimates of the reservoir properties (such as the coefficients of permeabilities K_g and K_f), the values of the rheological parameters (such as the coefficients of dynamical viscosity λ^* and η) are calculated previously, then the values of the parameters T, D_o, D, $b_{f.}$, $p_{res.}$, $p_{sd.}$, τ', τ'' must be obtained additionally. So, for example, Kelvin's temperatures (T) defines out of the temperature log data, and for the calculation of the opening of the microfissures the oil-field data concerning bedded ($p_{res.}$) and mining ($p_{sd.}$) pressures are used.

The totality of the above-mentioned parametrical estimates for the determining of the image of the oil-and-gas deposit guarantees the correct identification of the images of various the oil-and-gas deposits. After the receiption of the estimates of the oil-field parameters procedures of the identification of the oil-and-gas deposit isimplemented by means of the optimal deciding rules based on Neyman - Pearson's criterion.

The example of the experimental tests and the applied use of the declared method. For the borehole seismic investigations such technical devices, as digital recorders, explosive sources, three-component one-modular sondes and other equipment have been used. The methods of the seismic data acquisition included: the excitation of the direct longitudinal wave by the near-surface source of the oscillations (the one shotpoint), digital registration of the longitudinal wave using downhole and check three-component one-modular sondes and detailed observations (ΔH = 2.5-5 m) of the 3C VSP for the recording the displacement vectors for longitudinal and shear (or transverse) waves on the perspective in the productive relation depth interval in the investigated borehole.

The results of the experimental diagnosis of the dynamical, rheological, absorbing, reservoir and fluid- properties of the rocks according to the detailed seismic investigation data, received on perspective in the productive relation an interval of depths 5030-5130m in exploratory borehole Lopushna - 13, which is located in the underthrust zone of the Pokutsko-Bukovynski Carpathians (Ukraine), are shown on Fig. 1 - 6.

The geological problem which has been formulated before the seismic survey in the borehole Lopushna-13 consisted in obtaining the quantitative estimates of the reservoir and fluid-saturated parameters for the possible perspective in the oil-and-gas-bearing relation thickness of Cretaceous depositions (argillites), which is located at the depths 5092.5 – 5105 m. The cap rock is located above the latter (low-porosity and low-permeable limestone). The results of the borehole seismic survey for the argillaceous thickness have shown the relatively high values of: granular porosity - Φ_g = (3.4 - 8.8)%; fissuring - $L_{d.f.}$ = (48 - 65) m^{-1}; granular permeability - K_g = (49 - 202)$10^{-3}mcm^2$ and fissured permeability - K_f = (16 - 40)$10^{-3}mcm^2$, which was accompanied by of the most part of the layer with such values of the fluid saturation coefficients: $k'^{,\prime\prime}_{f.s.}$= (91 - 93)% (Fig.5 - 6).

Thereby in the upper part of the layer (at depth of 5092.5 m) the zone of the tectonic dislocation has been diagnosed which is distinguished by the values of the interval coefficients of absorption $\alpha'^{,\prime\prime}(\overline{\omega})$ and the quality factors $Q'^{,\prime\prime}(\overline{\omega})$. Evidently the tectonic dislocation has changed sealing the deposit, earlier existing here, as the result of which only the residual oil in the upper part of the layer (at the depths of 5092.5 - 5095m) has been preserved. The subsequent oil-field tests of the given interval of depths have proved the above-mentioned prediction.

Owing to the detailed investigations by the method of the seismic survey in the borehole Lopushna - 13 the other zones with the anomalous values of the rheological and absorbing parameters of the rocks also have been identified (Fig. 3 - 4). According to the totality of the significant oil-field parameters (necessary for the identification of the image of the oil-and-gas

deposit) at the depths of 5030 - 5065 m perspective layers have been detected which consist from the terrigenous rocks of the Neogene.

Here the inhomogeneous reservoir is presented by the following parameters: Φ_g=(1.3 - 5.7)%; $L_{d.f}$=(19 - 44)m^{-1}; K_g=(7.9 - 92.6)$10^{-3}mcm^2$; K_f =(3.5 - 57.9)$10^{-3}mcm^2$ and $k_{r.w.}$= (6 - 16)% (Fig.5-6). The oil-and-gas deposit has the trilaminar disposition of fluid, which fills the pores and fractures of the rocks. In particular, the reservoir at the interval depths of: 5030 - 5037.5 m is gas-bearing; 5037.5 - 5047.5 m is oil-bearing; 5047.5 - 5052.5 m is water-bearing when the coefficients of fluid saturation vary within the following limits: from 84% up to 94% (for the granular part) and from 92% up to 95% (for the fissured part). It is necessary to indicate, that the above-mentioned oil deposit has been missed earlier when only the data of the standard complex of the well logging methods were used.

The measured coefficients of the effective attenuation ($\tilde{\alpha}'{,}''_{eff.att.}$) and dispersion ($\tilde{\alpha}'{,}''_{disp.}$) have the negative numerical values in the depth intervals: 5030-5050 m, 5092,5-5105 m and 5117,5-5030 m. The latest characterizes the presence of the zones with the anomalously high pressure in the above-mentioned layers which is proved by the direct oil-field measurements of the bedded pressures and temperatures. The numerical estimates of the bedded coefficients of attenuation, absorption and dispersion, received for the respective component of the direct longitudinal wave, are presented in Table 1.

Table 1 - The bedded coefficients of attenuation, absorption and dispersion of amplitudes of the direct longitudinal wave for the compression and shear components (the borehole Lopushna-13).

Depth H [m]	Compression component $\cdot 10^{-3}$ [m^{-1}]				Shear component $\cdot 10^{-3}$ [m^{-1}]				Lithology	Reservoir pressure, Temperature
	$\tilde{\alpha}'_{eff.att.}$	$\alpha'(\bar{\omega})$	$\bar{\alpha}'$	$\tilde{\alpha}'_{disp.}$	$\tilde{\alpha}''_{eff.att.}$	$\alpha''(\bar{\omega})$	$\bar{\alpha}''$	$\tilde{\alpha}''_{disp}$		
5030 - 5050	- 18,2	6,4 **oil**	14,1	**- 38,7**	- 24,3	0,9	14,1	**- 39,3**	Aleurolite	7,8 MPa 106°C
5055 - 5065	33,4	3,0 **water**	17,4	13,0	32,1	2,0	17,4	12,7	Sandstone Argillite	
5070 - 5090	18,3	7,8	1,2	9,3	11,5	1,3	1,2	9,0	Limestone	
5092,5-5105,0	- 38,0	4,5 **water,oil**	2,3	**- 44,8**	- 40,8	1,6	2,3	**- 44,7**	Argillite	7,6 MPa 106°C
5107,5-5115,0	32,5	9,7	- 3,2	26,0	23,5	0,7	- 3,2	26,0	Clayey sandstone	
5117,5-5130,0	- 44,1	2,3 **water**	2,4	**- 48,8**	- 44,2	1,5	2,4	**- 48,1**	Dense limestone	7,8 MPa 108°C

Then, using the totality of the reservoir and fluid-saturated parameters of the rocks, the interval of depths 5035-5050 m in the borehole Lopushna-13 was recommended for the baring of the

productive layers. The tests have passed successfully with the obtaining of the oil influx with the initial flow rate of 0.8 m^3/day out of the borehole that before had been considered as nonproductive.

The results of the experimental tests allow us to predict the areas of the applied utilization of the declared method of wave diagnostics of the oil-and-gas deposit, in particular:

- during the exploration drilling when it is necessary to detect the reservoir, cap rocks and the presence of the oil-and-gas-bearing layers;
- in the development drilling during the reservoir engineering of the oil-and-gas deposits when it is necessary to define more precisely the reservoir parameters of the productive layers, the quality of cap rocks, quantitatively to estimate the hydrocarbon saturation and to determine the locations of the gas-oil-water contacts;
- for the monitoring of the reservoir engineering of the oil-and-gas deposits.